THE WICHITA FORMATION OF NORTHERN TEXAS[1]

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With discussions of the Fauna and Flora by
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INTRODUCTION

The geology of the "Red Beds" area of northern Texas has long been recognized as one of the perplexing problems of North American geology. The interest aroused by the discovery in these beds of a fauna which was regarded by Cope, C. A. White, and others as Permian has brought forth a number of papers bearing on this region, most of which are based on transient visits in search of fossils, generally with scant attention to the detail of stratigraphy.

This paper is based upon investigations made in connection with the study of underground water conditions for the United States Geological Survey during the field seasons of 1906 and 1907. The collections of invertebrate fossils made in the course of the investigations were submitted to Dr. George H. Girty of the Survey, who also had for study additional materials collected by E. O. Ulrich in former years.

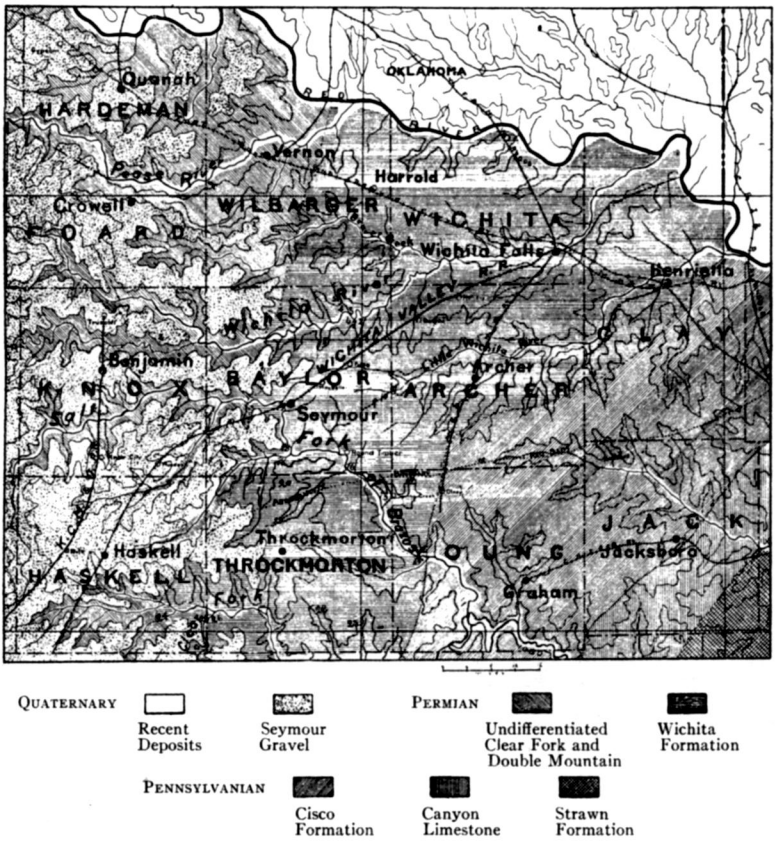
STRATIGRAPHY OF THE REGION

The "Red Beds" area.—The area occupied by the "Red Beds" in northwestern Texas is bounded on the west by the eastern escarpment of the Llano Estacado, and extends eastward along the Red River to Montague County, where the formations pass from sight beneath the basal beds of the Cretaceous. From this point the eastern boundary of the "Red Beds" bears south and then westward, following approximately the lines between Jack and Clay, and Young and Archer counties as far west as the Salt Fork of the Brazos. From this point it bears southwestward to the south-

[1] Published by permission of the Director of the United States Geological Survey.

eastern corner of Haskell County, thence irregularly south until it meets the Cretaceous again in Concho County.

As thus outlined, the "Red Beds" occupy an area of irregular shape 80 to 100 miles in width in the southern portion, while at



the north they extend eastward fully twice that distance along the south side of Red River. If a line be drawn from a point on Red River near the mouth of Pease River southwestward through Seymour to the northeastern corner of Haskell County and thence southward, it will mark approximately the eastern boundary of a series of red clays and red sandy shales containing gypsum in varying amounts, to which the names Clear Fork and Double Mountain

were applied by Cummins in reports of the Texas Geological Survey. These are evidently the equivalents of the beds included by Gould[1] in the formations to which he applied the names Greer and Quartermaster. As these beds have no connection with the problem in hand, they may be dismissed from further consideration. It is to that portion of the "Red Beds" area adjoining the Red River and extending eastward from the line above indicated that most of the discussions concerning the Texas Permian apply. This is the type area of the Wichita formation of Texas. The western part of this area is characterized by the occurrence of beds of limestone and blue shale interbedded with red clays and sandstones, while the eastern part is notable for the entire absence of limestones and the very limited development of blue shale and clay. If a line be drawn from a point where the Salt Fork of the Brazos crosses the boundary between Throckmorton and Young counties, a little east of north to Red River, it will mark approximately the boundary between the areas thus lithologically distinguished. According to Cummins' earlier writings[2] most of the rocks of this western area were assigned to the Clear Fork formation, while the strata occurring toward the east constitute his original Wichita division. Many of the fossils on which his conclusions regarding the Permian age of the beds were based, however, appear to have come from the basal portion of the limestone series in eastern Baylor County.

In the earlier reports the Wichita formation is described as having no surface development south of the point where the "Red Beds" boundary meets the South Fork of the Brazos River in the northeastern corner of Throckmorton County. From that point southward the Clear Fork formation is said to rest directly upon the "Albany," considered to be the highest division of the "Coal Measures" in that region. This peculiar relation of the Wichita formation was conceived to be due to overlap, and hence it was believed that an unconformity marked the relations of these beds to the "Coal Measures." In a later paper,[3] read before the Texas

[1] Charles N. Gould, *Water-Supply and Irrigation Paper No. 191* (1907), 14–19.

[2] *Geological Survey of Texas*, II (1890), 401. See map facing p. 552.

[3] W. C. Cummins, *Transactions of the Texas Academy of Science* (1897), II, 93–97.

Academy of Science, Cummins announced the discovery of evidence showing that the limestones of eastern Baylor County are the same as those of the "Albany." In this paper the beds of Baylor County are said to constitute the upper part of the Wichita. Owing to the discontinuance of the Texas Survey the report on this area prepared for the *Fifth Annual Report* has not appeared.

Rocks of the Wichita area.—East of Baylor County the rocks consist for the most part of red concretionary clays, red sandstones and sandy shales with occasional beds of blue shales, and bluish to grayish-white sandstones. Limestones are conspicuously absent. Occasional impure nodular layers occur, however, which contain considerable calcareous matter, but these do not constitute strata of limestone. The sandstones are usually soft and distinctly cross-bedded. In some places they are shaly, in others massive. Some layers are streaked and specked with grains of black iron oxide, while others contain nodular masses and concretions of iron ore.

The clays are mostly deep red or red mottled with bluish-white and drab colors. The red clays contain an abundance of nodular concretions of irregular shape varying in size from that of a pea to masses 4 or 5 inches in diameter. They consist of clay, iron, and lime, and at times are hollow or with the interior filled with calcareous clay or lime carbonate. In some cases they are flattened and stand in vertical position in the clays, suggesting their origin through the filling of fissures.

Occasionally a bed is met with consisting of rounded lumps of hardened clay cemented together by ferruginous matter, representing what Cummins called "a peculiar conglomerate." This formation is believed to have had its origin in the breaking-up of a bed of clay by running water or wave action.

In places the bluish clays are copper bearing. Efforts to mine these deposits, however, have not been profitable. The ore occurs in the form of small nodules in the clays and also as a replacement of wood.[1]

In the sandstones occasional traces of plants occur, and sometimes remains capable of identification are found. White reports *Taeniopteris* from the sandstones near Fulda. The stratification

[1] J. F. Cummins, *First Annual Report, Geological Survey* (Texas, 1889), 188–96.

of the beds is very irregular. The sandstones, shales, and clays grade into each other both vertically and horizontally. Moreover there is a monotonous similarity in the sandstones and shales respectively throughout the area, which, taken in connection with the absence of any persistent easily recognizable stratum, renders the stratigraphic correlation of the beds, except within very narrow limits, practically impossible.

In eastern Clay and Montague counties, the beds, considered Cisco, show a greater development of sandstones some of which are conglomeratic. In the western part of the area, however, no true conglomerates were observed.

As to the thickness of the Wichita, no definite statement can be made. Certain of the beds may be traced for a limited distance sufficient to indicate a general westward dipping of the strata. Cummins estimates it to be 35 feet per mile, which is probably too high. The width of the outcrop in an east-west direction is about 50 miles, which, assuming a regular inclination of 25 feet per mile, would give a thickness of 1,250 feet for the beds outcropping in this portion of the field. How much of this should be referred to the Cisco is conjectural, but probably not less than half. A well put down for oil at Electra, which is located near the top of the formation, passes through 1,790 feet of red clays with some sandstone and red sandy shales. At Petrolia, which is near the middle of the outcrop, the oil wells are for the most part about 400 feet deep, chiefly in red clays and shales. Drilling has extended to a depth of 800 feet in some instances and indicates an increase in the proportion of blue shales below, but no reliable record could be obtained of the lower formations passed through.

At Archer City a well 737 feet deep shows red clays and reddish sandstones predominating to a depth of 670 feet. Below this the drill revealed similar deposits but in diminished proportion, as compared with the light-colored sands and bluish clays. Since the upper beds of the Cisco in this region are prevailingly red, however, no reliable conclusion can be drawn from well records as to the plane of division between the formations.

In the bluffs of the Wichita River in the northwestern corner of Archer County some beds of limestones aggregating 4 feet in

thickness appear at the top of the escarpment on the west side of Horseshoe Lake, and outcrops of these appear at intervals along the boundary of Archer and Baylor counties. This limestone is earthy, very hard, dark blue where fresh, and weathers to dark brown or black. It is underlain by 4 feet of blue clay. The remainder of the section to the base of the hill, about 100 feet, consists of red concretion-bearing clays with a limited development of red and white shaly sandstone. From this point westward the stratification becomes more regular, consisting of the blue shales alternating with the red, the red being predominant, with an occasional bed of dark earthy limestone containing usually an abundance of poorly preserved fossils.

At the Bar-X ranch on the Wichita River in the northeast corner of Baylor County near the Old Military Crossing, several ledges of hard limestone appear in the river bluffs separated by varying thicknesses of blue shale, alternating with red clay. The beds dip to the westward at inclinations estimated at 20 to 30 feet per mile. Proceeding up the river from this point, limestones appear at intervals in increasing development, the best outcrops occurring about 2 miles east of where the Seymour-Vernon road crosses the river. Here an escarpment 90 feet in height has the lower two-thirds composed of red and blue shales alternating with beds of limestone. The middle of the section consists of red and concretionary clays and sandstones. Some of the ledges of limestone are massive, but others are thin-bedded and shaly, and separated by varying thicknesses of bluish clay. Locally the thin-bedded limestones and their included shale grade horizontally into more massively bedded limestones. Fossils are not plentiful in this locality. The same beds are exposed again northward in the banks of Beaver Creek. At Seymour the limestones are well exposed in the banks of the river where they are quarried to some extent and furnish a stone that is well adapted to ordinary uses. The beds are here transected by the Salt Fork of the Brazos River, which flows in a relatively narrow valley between steep bluffs 200 feet high, made up of interbedded red and blue clays, and limestones.

The limestones of Baylor County area are generally fossil-

iferous. Owing to the hardness of the rock, however, good specimens are difficult to obtain. Toward the south there is an increase in the development of blue shale and limestone, while the red clays and sand show a corresponding diminution. In a recent paper[1] Case has endeavored to correlate certain of the sandstones occurring throughout the area, one of which he calls Fulda, from a little station by that name in eastern Baylor County. With this sandstone he correlates others which outcrop as far east as Wichita Falls, a distance of 37 miles. With this conclusion the writer is not in accord. In the first place, the sandstones at Fulda are underlain by some thin limestones which outcrop toward the northeast in the northwestern part of Archer County. It is quite apparent that the sandstones in eastern Archer and Wichita counties represent horizons below these limestone beds. Assuming the general westward dip of the strata to be no more than 20 to 25 feet per mile, there must be a descent of not less than 650 to 800 feet to which must be added the rise of the plateau surface which is about 200 feet, making a total of 850 to 1,000 feet between the horizon represented at Wichita Falls and that at Fulda and rendering untenable the correlations suggested.

Albany area.—The eastern boundary of the Clear Fork and Double Mountain formation in eastern Jones County is marked approximately by the Clear Fork River. The region to the east of this point to the limits of the Cretaceous in western Parker and Wise counties, a distance of over 100 miles, known as the Brazos Coal Field, is occupied by rocks of Carboniferous age. These beds, which have a thickness of nearly 7,000 feet, present lithological, stratigraphic, and faunal characteristics, which permit their separation into four well-marked divisions, known as the Strawn, Canyon, Cisco, and "Albany" divisions.[2] Southward in the Colorado Coal Field the equivalent rocks were first studied by Tarr,[3] who

[1] E. C. Case, *Bulletin of the American Museum of Natural History*, XXIII (1907), 659–664.

[2] These names appear first in the *First Annual Report of the Geological Survey of Texas* in the State Geologist's "Report of Progress," pp. lxv–lxvii. Hill, however, credits them to Cummins (*Twenty-first Annual Report, U.S. Geological Survey*, Part VII, 97).

[3] R. S. Tarr, *First Annual Report of the Geological Survey of Texas* (1889), 201–16.

subdivided them into five divisions as follows: Richland, Milburn, Brownwood, Waldrip, and Coleman. Later the Milburn was included in the Brownwood.[1] The relations of these rocks as now recognized are as follows:[2]

Colorado Field (Tarr)		Brazos Field (Cummins)	Thicknesses in Feet
Coleman		"Albany"	1,200
Waldrip		Cisco	800
Brownwood	Brownwood	Canyon	800
Milburn			
Richland		Strawn	4,100

The beds dip to the west at a low inclination estimated by Cummins to be 30 feet per mile for the "Albany" and 75 for the Canyon.

Limestones constitute the dominant characteristics of the "Albany" and Canyon formations, while sandy shales and sandstones, with some conglomerates, make up the larger part of the Strawn and Cisco formations. It is with the two uppermost of these, the "Albany" and Cisco, that the "Red Beds" problem is concerned.

The "Albany."—The "Albany," named from the county seat of Shackelford County, consists of blue, gray, and yellowish limestones, alternating with beds of blue and dark-gray shales. The upper 500 feet are characterized by massive beds of hard blue limestone, with partings of blue shale, while the lower portion shows a greater development of shale, the limestone being for the most part thin-bedded and shaly. The heavy ledges of limestone appear at the surface in a succession of terraces which extend in sinuous curves from north to south. Sandstones and conglomerates are almost entirely lacking. The formation contains an abundant marine fauna, which, taken in connection with the notable development of limestones, indicates deep seas and quiet conditions of deposition. Above, the formation grades rather abruptly into red gypsiferous clays and red sandy shales and sandstones. The base of

[1] R. T. Hill, *Twenty-first Annual Report of the U.S. Geological Survey*, Part VII (1899, 1900), 98.

[2] The thicknesses cited are those given by Drake, "Report of the Colorado Coal Field of Texas," *Fourth Annual Report, Texas Geological Survey* (1892), 371–446.

the formation is placed just below the main limestone and the blue shale series, the line marking the boundary with the Cisco coinciding approximately with the east line of Shackelford County.

The Cisco.—Below the "Albany," and outcropping to the east of that formation, is the Cisco, which is composed of sandstones and shales, with some conglomerates and two or three beds of coal. Occasional beds of limestones occur in the lower part of the formation and again near the top. Coal outcrops along the Salt Fork of the Brazos River west of Graham in Young County, and elsewhere to the northeast and southwest. Some of the beds of coal are associated with limestones, in one case a thickness of two or three feet of limestone resting directly upon a bed of coal. The conglomerates consist of sub-angular fragments of flinty blue limestone and chert cemented together by a ferruginous sand. Nodules and hollow concretions of limonitic iron ore are common. These conglomerates have been recognized at two different horizons and in widely separated localities. Their exact relations, however, have not been clearly defined. In Stevens County the clays are mostly blue and yellow. Limestones appear at intervals, but these thin out northward, while the clays show a corresponding increase in development.

Relation of the "Albany" to the Wichita.—When traced northward, the limestones of both the "Albany" and Cisco formations diminish in thickness, while there is a corresponding increase in the intervening beds of shale. In the case of the "Albany" the limestones show also a change, becoming more earthy and irregular in their texture, and some of the beds passing into gray indurated clays. The few limestones in the upper part of the Cisco formation disappear entirely in the northern part of Young County. Along with this change there is an increasing development of red clay, alternating with the blue. The massive beds of limestones constituting the upper part of the "Albany" along the Clear Fork in northwestern Shackelford County and in western Throckmorton County were traced northward as far as Beaver Creek in eastern Wilbarger County. They appear in more or less continuous exposures as far north as Seymour, north of which they are covered, but are again exposed, greatly diminished in thickness on Big

Wichita River and Beaver Creek in the line of their strike northward. Greater difficulty is encountered in the effort to trace the lower beds of the "Albany," owing to the greater proportions of clays and sands and the disturbed condition of sedimentation, both conditions becoming more pronounced as the beds are followed northward. Certain of the limestone beds, however, are persistent, although showing changes in their physical character, and by means of these the eastern boundary of the formation was ascertained with a fair degree of accuracy. At Fane Mountain, a low elevation in the southeastern corner of Throckmorton County, is an outcropping of limestone characterized by an abundance of *Myalina permiana*. These beds occur at intervals northward in eastern Throckmorton County, and at Spring Creek in the northwestern corner of Young County they outcrop in the bank of the river about a mile from the post-office. Here the beds show locally a gradation into sandstone suggesting near-shore conditions of sedimentation. On Godwin's Creek, in the western part of Archer County, the diminished representatives of these, or possibly somewhat higher, beds appear, as also farther north on the Big Wichita River. The limestone which outcrops on the Big Wichita north of Fulda, referred to on p. 116, is evidently one of the lowermost beds. The most northerly appearance of presumably the equivalents of these beds was noted in the vicinity of Electra in the western part of Wichita County, where occasional plates of limestone appear over the surface apparently as a result of the weathering out of lenses of limestone in the clays. In the case of the Cisco formation the changes which these undergo toward the North have not had careful study. The limestone, however, appears to thin out entirely in the northern part of Young County, there being no representatives of these formations in the "Red Beds" area except it be the impure, calcareous nodular beds described above.

Nowhere in the southern area so far as observed are there any indications of unconformity. Notwithstanding the lithological and faunal characteristics which distinguish the "Albany," these beds appear perfectly conformable with the Cisco below and the Clear Fork above, nor is there within the formation any indication of stratigraphic discordance. The change in the lithological character

of the beds toward the north is evidently the result of differences in the conditions of sedimentation. The character of this part of the formation suggests very strongly its origin on a coastal plain, or river delta, to the south and west of which lay the sea in which were deposited the marine "Albany" sediments. The interrelations of the two kinds of sediments suggest oscillation of the shoreline upon a relatively wide coastal plain. These changes may be explained as the result of oscillation of the land surface or, possibly better, by the slow but intermittent sinking of the coastal region.

As suggested by Case,[1] Beede,[2] and others, the materials of the "Red Beds" were evidently derived from a land mass on the north, of which the Wichita and Arbuckle mountains are the remnants. The following quotation from Beede's paper is especially pertinent:

> The Arbuckle and Wichita mountains are probably the source of much of the red sediment in which they are partially buried, and the former mountains are directly responsible for the eastern extension of these beds in central Oklahoma. The extent to which the lighter colored sediments of Kansas and Texas are replaced by red sediments in Oklahoma and near it represents in a rough way the limits of the influence of these mountains on the deposits of the time by the spread of their sediments. By the time the deposition of the light colored sediments had ceased the conditions had become such that nearly all the sediments derived from the land surrounding the basin were red.

FAUNAL RELATIONS

In the course of the field work collections of fossils were made at many localities, chiefly in the region occupied by the "Albany" beds. At the close of this paper is given a list of the invertebrate fossils obtained from the Albany and Wichita areas. The list includes the collection made by the author, and those made several years since by Mr. E. O. Ulrich. The localities are indicated on the map by corresponding numbers. These remains indicate, according to Dr. Girty, a marked identity in the invertebrate faunas of the Albany and Wichita areas. In the collections several different faunas can be discriminated. One of these has the brachiopod

[1] E. C. Case, *Bulletin of the American Museum of Natural History*, XXIII (1907), 659–64.

[2] J. W. Beede, *Journal of Geology*, XVII (1909), 714.

element fairly well represented, *Derbya cymbula* being generally present, and the pelecypod *Myalina deltoidea* rather abundant. Another contrasting fauna has, as a rule, brachiopods absent or greatly diminished, but is plentifully supplied with large nautiloids. The faunas appear to have been contemporaneous, both occurring throughout the formation, but in different localities. The nautiloid facies, however, is more prominent in the upper series of beds.

The invertebrate remains of this region were studied by C. A. White,[1] who considered them to be Permian. A map on which the localities were shown was prepared for the *Fifth Annual Report* of the Texas Geological Survey, but never published.[2]

The collections of vertebrates, which in past years have attracted so much attention, were made in the adjoining portions of Baylor and Archer counties. Cope, who first studied them, considered them to be of Permian age. A description of the localities where these remains were discovered has only recently appeared in print.[3] From this description, which is not accompanied by a map, it appears that no fossils were obtained east of the middle of Archer County. In late years interest in the vertebrate remains of the Wichita formation has been renewed and much new material has been obtained, more particularly through the labors of Williston and Case. The results of their investigations have appeared in various papers.

The plant remains from this region have been studied by Fontaine and White[4] and by David White. The last named spent several days in the field in 1909 and collected considerable material from two near-by localities, one, two and one-half miles south of Fulda, and the other four miles southeast of that place. As provisionally identified this material is as follows:[5]

[1] C. A. White, *U.S. Geological Survey Bulletin* 77 (1891).

[2] *Transactions of the Texas Academy of Science* (1897), 95.

[3] W. C. Cummins, *Journal of Geology*, XVI (1908), 737–45.

[4] I. C. White, *Bulletin of the Geological Society of America*, III (1892), 217–18. Study based on identifications by W. N. Fontaine.

[5] No. 1: Cassil Hollow, two and one-half miles south of Fulda, Texas. No. 2: Breaks of the Little Wichita, one-half mile south of the river, and four miles southeast of Fulda, Tex. The beds are just over the bone-bearing limestone. The species in bold-faced type are characteristic of the Permian.

Locality No. 1

Pecopteris arborescens
Pecopteris hemitelioides
Pecopteris densifolia?
Pecopteris grandifolia
Pecopteris mertensioides?
Gigantopteris sp. (cf. nicotianifolia)
Neuropteris (cf. lindahli)
Aphlebia sp.
Taeniopteris multinervis
Annularia spicata
Sphenophyllum? sp.
Sigillariostrobus hastatus
Walchia schneideri?
Gomphostrobus bifidus
Cardiocarpon n. sp.
Carpolithes sp.
Pelecypods
Estheria and fish scales

Locality No. 2

Pecopteris hemitelioides
Pecopteris grandifolia
Pecopteris candolleana
Pecopteris tenuinervis
Diplothmema? sp.
Odontopteris fischeri?
Odontopteris neuropteroides
Neuropteris cordata
Taeniopteris coriacea?
Taeniopteris abnormis
Taeniopteris n. sp.
Sphenophyllum obovatum
Sigillaria sp. (leaf)
Gomphostrobus? sp.
Cordaites principalis
Poacordaites cf. tenuifolius
Walchia piniformis
Aspidiopsis sp.
Araucarites n. sp.
Cardiocarpon n. sp.
Insect wings
Estheria
Anthracosia
Ostracods and fish scales

CORRELATIONS

That the limestone series of Baylor County is the equivalent of the "Albany" formation of the southern area is fully established by both the stratigraphic and the faunal evidence. The beds in the northern area, which include the limestones, shales, and sandstones of Baylor County and the sandstones and shales of Archer and Wichita counties, constitute the Wichita formation. Our investigations therefore fully support the conclusions of Cummins[1] and Adams[2] as to the equivalency of the "Albany" and Wichita formations.[3]

[1] W. C. Cummins, *Transactions of the Texas Academy of Science*, II (1897), 93–97.

[2] George I. Adams, *Bulletin of the Geological Society of America*, XIV (1903), 191–200.

[3] Along with the limestones of northeastern Baylor County which Cummins has designated as the top of the Wichita the writer would include the overlying beds of shale and limestone mapped by him as Clear Fork, which outcrop in the banks of the Big Wichita about a mile east of the Seymour-Vernon road and northward on Beaver Creek.

Gould[1] correlated the Clear Fork with the Enid, Blaine, and Woodward formations of Oklahoma. In making this correlation, he evidently followed Cummins' earlier writings, in which the beds of Baylor County were considered to be Clear Fork. Williston states[2] that the Enid formation of Gould is identical with the beds of Baylor County.

NOMENCLATURE

In the paper cited, Adams has contended that the terms Wichita, Clear Fork, and Double Mountain should be discarded as having no stratigraphical significance. In his latest papers, Cummins recommends the abandonment of the term Albany and the use of the term Wichita for the formation. In view of the conflicting statements that have been made as to the relations of the beds called Wichita we were at first inclined to agree with the first-named writer in recommending the abandonment of the term Wichita. Further consideration, however, leads us to conclude that with a revised definition it will be best to retain the name Wichita for the formation overlying the Cisco, which it is now generally agreed should be regarded as of lower Permian age, and to abandon the name "Albany."

The series of red clays and sandstones with their included gypsum deposits which in Texas overlie the Wichita formation and to which the names Clear Fork and Double Mountain have been given have not as yet received much study. With the limited amount of knowledge available the attempt to subdivide these beds seems to the author unwarranted, and they are, therefore, here mapped as "undifferentiated Clear Fork and Double Mountain."

CLASSIFICATIONS

The Permian age of the beds to which the name of Wichita was originally applied has been accepted quite generally, though there are not wanting those who regard the evidence as unsatisfactory. It was based chiefly upon the vertebrate and plant remains. In the southward, or "Albany," area the beds are wholly marine and

[1] C. N. Gould, *Water-Supply Paper No. 154*, U.S. Geological Survey (1906), 17.

[2] Letter to the author dated August 6, 1909.

destitute of both plants and vertebrates, though abounding in the remains of invertebrates. The Pennsylvanian aspect of this fauna has strongly impressed some investigators, including the author of this paper, and doubt was entertained as to whether the plane of separation between the Pennsylvanian and the Permian should be drawn at the base or at the top of the formation. The studies of David White, Beede, and others have contributed much in recent years to a knowledge of the Permian in American and in the main support the view of the Permian age of the Wichita formation. In a recent paper Beede[1] has ably discussed the Permian of Kansas, with which he correlates the "Red Beds" of Texas. Cummins correlates the beds of eastern Baylor County which he regards as the top of the Wichita formation with the Fort Riley limestone of the Chase group of Kansas. "It is quite certain that the Fort Riley horizon is the same as the Wichita of Texas and is at the very top of the division."[2] The top boundary of the Wichita formation was drawn by Cummins[3] at the top of a stratum of red clay overlain by thin beds of limestone and blue shales at a point on the Big Wichita four miles west of the east boundary of Baylor County. However, as we have shown, beds which are undoubtedly the same as those which appear at Seymour and southward in Throckmorton County appear in the banks of the Big Wichita River some eight to ten miles west of this point. The thickness of the strata included here, which overlie Cummins' topmost beds, and are here included with them in the Wichita formation, is estimated to be 250 to 300 feet. The whole limestone and shale series of Baylor County, thus included as the upper division of the Wichita formation, is provisionally placed at 450 to 500 feet, and consists, as shown elsewhere, of limestone beds of varying thicknesses separated by varying but usually great thicknesses of shale.

How much of this is to be correlated with the Fort Riley limestones can be determined only by more detailed stratigraphic and paleontologic studies. Cummins evidently intended to include

[1] J. N. Beede, *Journal of Geology*, XVII (1909), 710–29; *Kansas University Science Bulletin*, IV, No. 3 (1907).

[2] W. F. Cummins, *Transactions of the Texas Academy of Science*, II (1897), 98.

[3] *Second Annual Report, Texas Geological Survey* (1891), 402, 403; also *Fourth Annual Report* (1893), 224.

the lower beds only in his correlation. It may be that further studies will show that the overlying beds of the Winfield limestones of Kansas are represented here.

DISCUSSION BY GEORGE H. GIRTY

The equivalence in a general way of the fossiliferous late Carboniferous beds of Kansas and Texas has long been recognized and in both cases they have very generally been cited as Permian. Cummins,[1] partly on stratigraphic and partly on paleontologic evidence, reached the conclusion that the Fort Riley limestone of Kansas occupies a position at the top of the Wichita formation of Texas. The Fort Riley is the middle formation of the Chase group, the lowest group of the Kansas Permian, so that the bottom of the Wichita may well be as low as the base of the Permian of Kansas. This correlation of Cummins is probably the most precise and the best sustained of any, and it is also in accord with some recent paleobotanic evidence. Mr. White states in the present paper in discussing the fossil plants which he obtained from the Wichita formation that the latter is probably referable to the Chase group of Kansas.

Not until recently, it seems to me, has adequate evidence been adduced either for distinguishing the Permian of Kansas and that of Texas sharply from the underlying Pennsylvanian or for correlating them with the Permian of Europe. C. A. White found the Wichita fauna to have essentially a Pennsylvanian ("Coal Measures") facies, in which, however, certain characteristic Permian Ammonites occur. A similar conclusion seems to be demanded by the evidence of the present collections.

In all, 75 species have been discriminated in the Wichita collections which I have studied, the local distribution of which is shown in the table prepared by Mr. Gordon accompanying the present paper. The identifications naturally vary in precision and refinement. In many cases it has been possible to name only the genus to which a species belongs. This is sometimes due to the fact that the species is undescribed. In a few instances species have been cited by comparison with others, e.g., *Bellerophon aff. harrodi.*

[1] *Trans. Texas Acad. Sci.*, II (1897), 98.

If such citations are included as species identified, 48 species of the fauna are identified and 27 are unidentified. Of the 48 species identified, 37 are known to occur in the Pennsylvanian rocks of the Mississippi Valley. Most of them are cited by Dr. Beede in his table showing the Pennsylvanian faunas of Kansas. The large percentage of indeterminata introduces a considerable possibility of error in the inference that 75 per cent of the fauna of the Wichita formation consists of well-known Pennsylvanian types, but it is undoubtedly true that in the main this fauna has a Pennsylvanian facies. One or two new forms at present excluded from the identified species would somewhat decrease this percentage. On the other hand, of the 25 per cent which is not known to occur in the Pennsylvanian of the Mississippi Valley, relatively few species are characteristic of the Permian of that area; still fewer, if any, are characteristic of the Permian of Europe. Some of them occur in western faunas, probably contemporaneous with the eastern Pennsylvanian. *Bellerophon subpapillosus* is one of these. Twenty-five in a hundred, therefore, far overstates the percentage of characteristic Permian species. Such percentage, however, might be considerably increased by the inclusion of certain species known to occur in the Wichita formation but not represented in the Survey collections. I refer especially to the Ammonite forms described by C. A. White from the Military Crossing of the Wichita. These are by all means the most diagnostic Permian types of the fauna. How little characteristic of it they really are, however, is shown by the fact that later collections made at the same place fail to contain them, although a special search was made to secure additional representatives.

Mr. White finds that about 50 per cent of the Wichita flora consists of species characteristic of the Permian, while most of the remainder are known to occur in rocks regarded as of Permian age. If we omit the fauna of the Kansas Permian, to include which would be a sort of *circulus vitiosus*, no condition comparable to this has been demonstrated by the invertebrate fossils and, in so far as I have seen the evidence, no such condition exists. I am, therefore, accepting the Permian age of the Kansas and Texas beds, but at present strictly on the paleobotanic evidence.

If the upper part of the Carboniferous section of Texas is to be discriminated as Permian, the line of division, as indicated also by the paleobotanic evidence, would probably best be taken at the base of the Wichita.

An inspection of the faunas collected from the strata immediately concerned in this report shows a rather noteworthy change of facies between the Wichita and the Cisco—a change, however, which is more or less progressive and has its beginning in earlier beds. This shows itself rather in a limitation than in a change of fauna and in the prominence of certain groups more rare below. Thus the brachiopods, pelecypods, gasteropods, etc., are much less in evidence in the Wichita than in the Cisco, but, as already pointed out by C. A. White,[1] they are essentially the same as those of the normal Pennsylvanian fauna. In the Wichita, however, we have a remarkable development of the Cephalopoda, which in the earlier sediments are rare.

Just what significance faunal changes of this sort possess it is difficult to say. It seems to be a change comparable to that which is more strikingly illustrated when a thin calcareous sheet with a marine fauna occurs in the middle of a coal deposit. Here, of course, there is an absolute change from the animal life of the calcareous stratum to the plant life of the coal and roof shale, but in this case the significance is not ambiguous and it is clearly not stratigraphic.[2] So I think the faunal change marked by a substitution of one predominating animal type for another may often be more safely interpreted as environmental than as stratigraphic in its import. At the same time the stratigraphic significance may be present also, which would appear to be the case with the Wichita auna, as indicated by the fossil plants. Nevertheless, this change, as marking the evolution from one geologic period to another, would be more impressive if the molluscan and molluscoidean groups were continued into the Wichita and with a difference of facies such as is usually found when the faunas of other systems are contrasted.

[1] *U.S. Geol. Surv., Bull. 77* (1891), 30–39.

[2] I mean of course that there is usually no time break and no appreciable change of fauna in the general region accompanying the phenomenon.

In connection with the correlation of the Wichita formation with the Permian of Europe, it may be well once again to consider the use and definition of the term Permian.

As is well known, Murchison correlated with the English "Millstone grit" a series of sandy beds which underlies the typical Russian Permian, and therefore this series, to which the name Arta beds or Artinskian was subsequently given, was distinctly excluded from the original or typical Permian. It has since been recognized that the Arta beds are not the equivalent of the "Millstone grit," and that the fossils which they contain show affinities with both the "Upper Carboniferous" below and the Permian above. The Artinskian therefore came to be called also "Permo-Carboniferous," and by many writers it is included with the other under the name Permian.

While the typical Permian is usually underlain by the sandstones of the Artinskian, over a considerable and well-defined area a heavy series of limestones and dolomites has been found to intervene. This apparently lenticular mass has been called the Kungur-stufe, and on paleontologic evidence has been by Tschernyschew united with the Artinsk and included under the term "Permo-Carboniferous," which, therefore, comprises two divisions, the Arta beds below and the Kungur beds above.

Now, the propriety of including the original Permian and "Permo-Carboniferous" in a single group is, of course, a question quite apart from the nomenclature which should be used, and it is a question with regard to which one who has not studied the rocks and fossils in the typical region can hardly render an authoritative opinion. There seems to be European authority both for excluding the "Permo-Carboniferous" from the Permian and for including it with it, the greater number of writers, it may be, adopting the latter course.

As for the plants, Mr. White states that "from the paleobotanical standpoint the Artinsk stage of Russia is clearly Permian."

My own knowledge of the facts is only that of the library, but I should judge that the faunal break was greater between the Gschelian and the "Permo-Carboniferous" than between the "Permo-Carboniferous" and the original Permian. That is, of the

very varied brachiopod fauna described by Tschernyschew from the Gschel but a small number of species appear to pass over into the Artinsk, and I infer that much the same is true of other groups. Both for this reason and because the Artinsk seems to introduce a new "cycle of deposition," I would be disposed to group the "Permo-Carboniferous" with the beds above rather than the beds below, not feeling, however, that my opinion on this point deserves much weight.

Now, while there may be diversity of opinion about grouping together the "Permo-Carboniferous" and Permian, all must agree that it is bad usage to employ the name Permian in two different senses, especially for the whole and at the same time for a part. Although the question is international as well as national, the proposition to remedy the present unfortunate condition would come with greater force and propriety from European writers. To me, personally, it is naturally a matter of indifference whether the term Permian is used for the series and a new name introduced for the beds above the "Permo-Carboniferous," or used for the beds above the "Permo-Carboniferous" and a new name introduced for the series.[1] The former alternative has in its favor the fact of perhaps greater usage; the latter, that it is the original and authoritative usage. I cannot believe that the unscientific procedure of employing the term in two senses will continue indefinitely, and consequently whatever we now do, short of the fundamental courses just named, must be more or less of a makeshift. It does not, perhaps, make much difference which method is adopted in this provisional manner, but as the main object is to be clear and exact, it has to me seemed the better plan to use Permian in the original and authentic sense.

It seems to me obvious that the Artinskian and Permian should be assembled under one division or separated into several, entirely as the sum of the evidence from all sources dictates. I have not the personal acquaintance with the beds, their faunas and floras, their field relations, etc., which would entitle me to an opinion of my own as to how they should be classified. It seems to be a moot

[1] Possibly some older name could be revived for the Permo-Carboniferous and Permian, such as Dyas, as suggested by David White.

point whether the Arta beds should be regarded as a separate division or included with the Permian, and it matters little for purposes of correlation whether an American writer follows one group of authorities rather than the other. Personally, I am quite willing to include them both in a single division of the time scale, and although believing that propriety would be better served by retaining Permian for only the upper division, I am willing to extend that term to cover the entire series because of the usage which it has received in this sense, but I am not willing, for reasons which must be obvious, to call the whole Permian and the upper part also Permian, and for the sake of precision I have been temporarily calling the upper beds Permian, the lower beds "Permo-Carboniferous," and the whole "Permo-Carboniferous" and Permian. If, in my Guadalupian report and elsewhere, I restricted the term Permian to the supra-Artinskian beds, it was done as a matter of procedure in nomenclature. I had no opinion of my own as to the classification of the beds to express or defend, although, if I had, excellent authority could be named in support of my position.

DISCUSSION BY DAVID WHITE

The plant material collected by myself from the breaks of the Little Wichita River near Fulda, Tex., is derived from two near-by localities, both near the middle of the Wichita formation. The fossil plants previously listed by Fontaine and White from two other localities, and recorded[1] by them as Permian, appear to represent a mixed flora, one of the localities being under suspicion of Pennsylvanian age. Neither of the latter two localities was visited by me on account of the lack of time; but on the basis of information received, I am disposed to believe that the stratigraphically lower beds at Antelope are probably Pennsylvanian.

The identifications given on p. 122 are provisional. Later it is hoped, when the material will have been increased both geographically and stratigraphically, a formal report covering the floras of the "Red Beds" will be prepared. The species printed bold-face in the lists on p. 122 are characteristic of the Permian. They point somewhat distinctly to the Rothliegende age of the beds.

[1] *Bull. Geol. Soc. Amer.*, III (1892), 217.

All the Old World species in the lists occur in the Permian of western Europe, and of the remaining species apparently every one which is not new is found in the Permian of Kansas. *Taeniopteris*, in simple fronds, is represented by several species characteristically lower Permian. Other types proper to the Permian are the *Odontopteris* form, the genus *Gomphostrobus*, *Annularia spicata*, the *Sphenophyllum* forms, one of which approaches *S. stoukenbergii*, and the scales provisionally referred to *Araucarites*, while the presence of *Walchia* assures a horizon as high as the highest "Coal Measures."

The presence of *Gigantopteris*, abundant at locality No. 2, is particularly notable since the genus is not definitely known except from the coal fields of central and southern China, where it occurs in beds associated with the coals overlying other terranes which, on the evidence of their contained invertebrates, have been referred by the French geologists to the lower Permian. The genus is certainly close to, if not actually identical with, a form described from several small fragments from the Permian of the Ural region.

In accordance with the paleobotanical standards of western Europe, I refer the plants of the Little Wichita in Texas to the lower Permian, the terranes being probably referable to the Chase group in Kansas. In this connection it should be observed, however, that the Artinskian flora of the Urals is essentially Permian, and that paleobotanists universally agree with the general usage of the geologists of western Europe in referring the Artinsk to the Permian.

DESCRIPTION OF LOCALITIES

NOTE.—The number at the left is the locality number as given at the head of the list and indicated on the map. The first numbers following the description of locality are the Survey permanent record numbers, the second the temporary or field numbers.

1. Bar-X Crossing, Big Wichita River, three miles north of Fulda Station, 5247 (GI. 67).

2. Bluff of Wichita River, one mile west of Bar-X ranch house, 5243 (RI. 29).

3. One mile east of Old Military Crossing, Wichita River, 7025*a*.

4. Two miles north of Wichita River, near Old Military Crossing. 7025*b*.

LOCALITY LIST OF INVERTEBRATE FOSSILS FROM THE WICHITA FORMATION, TEXAS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Allerisma terminale									×									×	×							
terminale var																										×
Ambocoelia planiconvexa																			×							
Annelid n.g.n.sp									×	×	×										×				×	
Aviculipecten aff. whitei														×											×	
sp															×							×				
Aviculipinna nebraskensis																								×		
peracuta							×		×											×	×					×
sp																		×							×	
Astartella concentrica												×														
Bakewellia? sp							×																			
Bellerophon crassus			×			×			×									×	×						×	×
aff. harrodi												×														
sp				×																						
Bucanopsis meekana													×													
Chonetes sp																		×								
Composita subtilita																			×			×				
Coloceras globulare								×	×		×							×	×							
Deltopecten occidentalis																								×		
Dentalium sp																×										
Derbya cymbula													×			×		×			×	×				×
sp							×					×														
Entomis sp									×																	
Estheria dawsoni							×																			
Euomphalus pernodosus																										×
catilloides											×															
sp							×																			
Euphemus subpapillosus									×																	
Fusulina sp																		×	×							
Fistulipora sp																			×							
Fenestella sp																										
Leperditia sp			×			×		×	×								×	×								
Lingula aff. tighti							×																			
aff. carbonaria								×																		
sp														×												
Lophophyllum profundum																			×							

Loxonema (sev. sp.)														×												
Meekella striaticostata																×										
Murchisonia aff. terebra															×	×										
sp.						×			×									×		×						
Myalina perattenuata																×										
deltoidea											×	×			×											
permiana		×	×	×	×				×							×	×		×			×	×		×	×
Nalicopsis sp.			×																	×						×
Nautilus sp.																		×						×	×	
Nucula aff. beyrichii																				×						
Orthoceras sp.								×	×	×						×			×	×		×				
Pelecypoda indet.										×																
Petellostium montfortianum															×											
Phacoceras dumblei							×									×			×					×		
Phyllopora sp.											×															
Plagioglypta aff. canna															×											
Pleurophorus calhouni			×			×										×										
subcuneatus									×					×			×	×	×	×		×	×			
sp.								×								×										
Productus cora																										
semireticulatus	×	×			×		×		×																	
Rhombopora lepidodendroides											×															
Schizodus compressus	×																									
ulrichi			×																							
sp.																										
Sedgewickia topekensis	×																									
Septopora biserialis											×															
Sphaerodoma intercalaris																×										
sp.															×											
Spirorbis sp.		×							×															×		
Stenopora sp.											×									×						
Strophostylus nanus																×										
peoriensis														×	×											
remex																×	×	×				×				
Tainoceras occidentale								×	×									×	×			×				
cavatum									×										×							
Temnocheilus aff. depressum									×											×					×	×
aff. forbesianum																×			×			×				
Zygopleura aff. rugosa									×																	

5. Four to five miles northwest of Old Military Crossing, Wichita River, 7025, 7025*c*.

6. Near Old Military Crossing, Wichita River, 7025*d*.

7. Three miles northwest of Fulda Station, near No. 2, 7026.

8. Four miles northwest of Mabelle Station (section house), 7028.

9. Eight miles southeast of Seymour, 5998 Deep Creek.

10. Head of Godwin Creek in eastern Baylor County, 7031, 7031*a*.

11. Godwin Creek near county line on Seymour-Archer city road, 5242 (R1. 29).

12. One to two miles northeast of Spring Creek, Young County (R1. 30).

13. One mile west of Spring Creek, 7035 (G1. 12, G1. 14).

14. Five miles south of Spring Creek, in Butte, 5216 (G1. 11).

15. Seven miles south of Spring Creek, Young County, 5217 (G1. 15).

16. Rocky Ford, Salt Fork, southeast corner of Baylor County, 5218 (G1. 9).

17. Quarry bank of Salt Fork, Seymour, 5220 (G1. 7).

18. West bank of Salt Fork, eight miles south of Seymour, 5222 (G1. 35).

19. Nine and one-half miles south of Seymour, Miller's Creek, 5221, 5224 (G1. 34).

20. Buttes, near wagon road, half-way between Throckmorton and Seymour, 7036 (G1. 32).

21. Three miles north of Throckmorton, 5215, 5227 (G1. 30).

22. Five miles west of Woodson, Throckmorton County, 5219, 5223, 5223*a* (G1. 25, G1. 26, G1. 27).

23. Fane Mountain, three miles southwest of Murray P.O., 5226 (G1. 24).

24. Paint Creek, southeast corner of Haskell County, 5245 (R1. 32).

25. Clear Fork, near southeast corner of Haskell County, 5231, 5232, 5241 (B1. 6, B1. 7, B1. 8).

26. Round Mountain on the Clear Fork, near 25, 5237, 5237*a* (R1. 34).